

TITLE: METHOD AND SYSTEM FOR STORAGE AND RECOVERY OF
VITAL INFORMATION ON RADIO FREQUENCY TRANSPONDERS

CROSS REFERENCES TO RELATED APPLICATIONS

The present application is a continuation-in-part of Application No. 10/373,628 filed 02/24/2003, which is a continuation-in-part of Application No. 10/167,227 filed 06/11/2002, which is a continuation of Application No. 09/330,786 filed 06/11/1999, now US Patent No. 6,404,325 issued 06/11/2002, which is a continuation-in-part of Application No. 09/227,649 filed 01/08/1999, now abandoned, which is a non-provisional application claiming the benefit of provisional Application No. 60/070,758 filed 01/08/1998; the contents of said US Patent No. 6,404,325, said Application No. 09/227,649 and said provisional Application No. 60/070,758 are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to the field of Radio Frequency Transponders and more specifically to retaining and restoring of valid state information by the Radio Frequency Transponders upon the reapplication of power.

Description of the Background of the Invention

Radio Frequency (RF) Transponders (tags) are used in a multiplicity of ways. They may be used in locating and identifying accompanying objects, as well as for transmitting information about the state of an object. It has been known since the early 60's that electronic components of transponders could be powered by a sequence of periodic signal bursts sent by

a "base station" and received by a tag antenna on each of the transponders.

5 The RF electromagnetic field induces an alternating current in the transponder antenna that can be rectified by a RF diode of the transponder, and the rectified current can be used for a power supply for the electronic components of the transponder. The current induced in the transponder antenna from the incoming RF energy would thus be changed, and the change in the
10 alternating current changes or modulates the RF power radiated from the transponder antenna back to the base station. This change in the radiated power from the transponder antenna is picked up by the base station antenna. Thus, the transponder antenna broadcasts a return signal without itself having a self
15 contained power supply.

The "rebroadcast" of the incoming RF energy is conventionally called "back scattering", even though the transponder broadcasts the energy in a pattern determined solely
20 by the transponder antenna. Since this type of transponder carries no power supply of its own, it is called a "passive" transponder to distinguish it from a transponder containing a battery or other energy supply, conventionally called an active transponder.

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As an example, consider an RF tag designed to respond equally well to signals at frequencies ranging from 2.425 GHz to 2.475 GHz in an ideal environment. In a less than ideal environment, where there are other RF tags, metal objects,
30 water-filled objects, etc. disposed in close proximity to a particular RF tag that is attempting to communicate with the base station, the RF energy available at a particular frequency

to be received by the particular RF tag may be attenuated. This situation is analogous to repositioning a TV or a radio antenna to get the strongest reception. Similar to the effect of the person repositioning the antenna on the reception of the antenna, the presence of other tags and/or objects interferes with the RF reception of a particular tag. Additionally to comply with the FCC regulations, the carrier frequency used by the base station hops over relatively narrow channels of up to 1 MHz wide in the allowed band, e.g., 2.400 to 2.483 GHz in the 2.450 GHz case, during communication.

When an array of tags is being interrogated by a base station, it is possible for very different field strengths to be available to tags depending on the carrier frequency of that channel being used by the base station at the time of the communication and on the different positions of tags in the array. For instance, a first tag at a first position may be well powered when the base station operates at 2.422 and 2.463 GHz but not at 2.447 GHz, while a second tag at a second different position may be well-powered when the base station operates at 2.463 GHz and 2.447 GHz, but not 2.422 GHz. These differences are related not to the RF tag design but to the instantaneous RF environment of the individual RF tag at the time the interrogation by the base station occurs.

If power being supplied to the RF tag has been removed for even short time duration, the state information being maintained or stored by the RF tag is lost. For example, when the RF burst powering the RF tag falls off, the tag power, which for passive tags is maintained by a storage capacitor, may be lost in as little as 100 microseconds. The state information of the RF tag is then also lost.

Losing the state information of the RF tag is particularly injurious when a base station sending a polarized RF is interrogating an array of RF tags having antennas polarized in different manners. When some RF tags may not be powered up by a particular frequency used, the communication protocol will attempt to talk to each tag in the array.

RF tags may have major and minor states. The major states may include the "ID," "READY," and "DATA-EXCHANGE" states. Each RF tag identifies itself to the base station in the "ID" state, lets the base station know that it is ready to transfer data in the "READY" state, and sends data in the "DATA-EXCHANGE" state. The minor states include information such as the counter value used during the identification protocol initiated from the base station.

When a RF signal burst of a first frequency is sent from the base station to an array of RF tags, some of RF tags in the array do receive sufficient power to operate from that signal burst and will proceed to operate through the stages or states of operation, such as entering the "READY" or "DATA-EXCHANGE" states. The RF tag is typically operated cyclically through those states; in each cycle the states are carried out in the order set out above. Thus if the base station knows in which state a particular tag is operating, it has an effective "book mark" as to where in the cycle this particular tag is operating. When the RF environment changes or when the base station hops to a new carrier frequency, some of the tags that were previously powered, will not now receive sufficient power and will no longer be able to operate. At the same time, other RF tags in the array that previously had insufficient power to operate will

now become powered up by the RF burst of the new frequency and start working.

5 An illustrative cycle of operation of the array of ten RF tags may be described as follows:

1. The base station or the reader is on channel one and RF tags 1-8 respond by beginning their participation in the identification protocol. All eight tags are successfully identified.

10 2. The reader now hops to channel two, the frequency of channel 2 allows tags 7-9 to be powered. Tag 9 will now respond by beginning participation in the identification protocol, while tags 1-6 lose their power and therefore stop participating. Since tags 7 and 8 were already identified and continue to be
15 powered sufficiently when operating on channel, they do not participate in the protocol.

3. The reader hops to channel 3. The frequency of channel 3 allows tags 2-10 to be powered. Tags 7-9 stay powered and do not participate in the protocol. However, tags 2-6 must be re-
20 identified in order to identify the one truly new tag 10.

The RF tags that are not well powered lose track of state information. This state information is essentially a bookmark in the communication sequence between the tag and the base
25 station. In running an ID protocol, for example, tags that newly enter the field as well as tags that have lost power and then regained it while remaining in the field are treated equally; they both have to be identified from scratch, wasting time. If state information could be maintained, the tags that
30 remain in the field and are not powered sufficiently even only for brief periods of time would not have to reenter the protocol

and thus system level performance with regard to tag identification would be improved.

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SUMMARY OF THE INVENTION

What is needed is for the state information of each RF tag to be maintained in order to prevent that RF tag from participating in the protocol with the base station, in
10 identifying previously unidentified tags of a tag array therefore improving system performance.

The present invention assures the integrity of state information retained by the RF tags during a loss of power. At
15 the time of the regular operation of each RF tag, the power is provided to a voltage-storing device, such as a capacitor, powering an information retention mechanism of the RF tag. The power source for that voltage storing device may be directed through a device such as a diode or a PFET, which may be
20 dedicated or shared with other components of the RF tag.

After the loss and reestablishing of power to the transponder but before the transponder restarts, the transponder checks the voltage-storing device powering the information
25 retention mechanism to determine whether sufficient power is present to retain information without corruption. Additionally, after the power is restored, the delaying circuitry of the transponder may delay the restart to assure proper determination of whether sufficient power is present. If sufficient power is
30 present, the transponder communicates a signal to indicate that fact, the stored information is restored and the transponder restarts.

BRIEF DESCRIPTION OF DRAWINGS

5 The foregoing objects and advantages of the present invention may be more readily understood by one skilled in the art with reference being had to the following detailed description of a preferred embodiment thereof, taken in conjunction with the accompanying drawings wherein like elements
10 are designated by identical reference numerals throughout the several views, and in which:

Figure 1 is a block diagram showing an exemplary Radio Frequency Transponder circuitry for retaining state information
15 during a period when power is not supplied to the transponder.

Figure 2 is a block diagram showing an alternative Radio Frequency Transponder circuitry where separate power sources are provided to power the circuitry and to charge a capacitor for
20 information retention.

Figure 3 is a block diagram showing an alternative Radio Frequency Transponder circuitry where a PFET transistor is used.

25 Figure 4 is a block diagram showing a Radio Frequency Transponder circuitry where voltage across a capacitor is measured to determine the state of retained information.

Figure 5 is a block diagram showing an exemplary voltage
30 check circuitry, which may be used by the present invention.

Figures 6a-c are time/voltage diagrams showing good and bad power levels.

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DETAILED DESCRIPTION OF THE INVENTION

Figure 1 of the present invention shows a RF tag 10 comprised of a diode 1, such as a Schottky or another type of diode, for accepting power from the main power line 6. The main power line 6 powers both, a main digital section 3 of the RF tag 10 and a capacitor C_{Aux} 5. The power accepted by the diode 1 is generated by the RF tag antenna 4 in conjunction with a well known power receiving circuit (not shown) when RF energy is received from a base station.

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The capacitor C_{Aux} is charged to a sufficient voltage to power a mirror latches mechanism 2 which may hold copies of state information of the RF tag 10. At any time during the operation of the RF tag 10, the processing of the main digital section 3 may place or save relevant information in to the mirror latches mechanism 6. This capacitor C_{Aux} is provided as a power source for the mirror latch mechanism 2 to enable it to retain the essential state indicators during the interval when the power supply to the RF tag is interrupted, for example the base station hops to a new frequency. The power from the capacitor C_{Aux} is provided to only a few transistors of the RF tag 10 and is not used to power up the clock or other RF tag 10 electronics. Therefore, the amount of required energy is small and may be provided by a relatively small capacitor.

Furthermore, when the power is restored or reapplied and the RF tag 10 restarts, the information retained in the mirror latches

mechanism 2 may be read back into the main digital section 3 to be used in the subsequent operation of RF tag 10 operation.

5 The information to be retained or saved may include both, the major and the minor state indicators. Some minor state information, such as the address from which the base station attempted to access data when the power is removed, need not be saved and may be allowed to be lost with little impact on the communication protocol initiated by the base station. That is
10 because the whole command including the address must be re-sent by the base station.

Figure 2 shows another embodiment of the present invention. In this embodiment, the power line 7 for the mirror latches
15 mechanism 2 is independent. The capacitor C_{Aux} is connected directly to the antenna-lead-in 4 and may illustratively use a Schottky diode 8 to rectify the RF energy received by the antenna which is not shown in the figure.

20 In yet another embodiment shown in Figure 3, a PFET transistor 9 may be used instead of the diode 1 (Figure 1). The supply of voltage V_{DD} 6 may vary very slowly, so that the transistor 9 may effectively rectify voltage for charging the capacitor C_{Aux} .

25 Turning back to Figure 1, please note that the size of the capacitor C_{Aux} and the leakage current therefrom determines the time interval during which the mirror latches mechanism 2 will store a copy of the state information. When the power sent to
30 the RF tag 10 from the antenna 4 is too low, the voltage V_{DD} 6 may fall below a threshold value sufficient to energize the RF tag electronics reliably. In such a situation, a power-no-good

signal (POK_), as shown in Figures 6a-c is issued by a separate RF tag circuitry to prevent the RF tag 10 from any further processing. Nevertheless, the mirror latches mechanism 2 will maintain the copy of the state information, for a period time
5 initiated when the RF tag is powered up and continuing as long as it takes for the leakage current to drain the capacitor C_{Aux} 5 through the mirror latches mechanism 2. Please note that when a RF signal burst of a different or second frequency is sent from the base station, other RF tags 10 in the array will be powered
10 up. Each RF tag may be energized by the RF signal bursts of different frequencies see the example described in the Background of the invention section. Hence, some RF tags from a first set may be powered up, by the RF signal bursts of frequencies other than the first frequency and will attempt to
15 change their state.

As explained, the inventive RF tag 10 is constructed to retain the state information that was stored in the mirror latches mechanism 2 during a first application of the RF signal
20 burst at a frequency suitable to power up that RF tag 10. The RF tag 10 will be powered until the base station performs a frequency hop to a frequency, which may or may not be suitable to power this particular RF tag 10 depending upon the RF environment of the tag array. The state information stored in
25 the mirror latches mechanism 2 is retained until the base station, at a later time, reapplies the RF signal burst suitable to re-power up the RF tag 10 to the set threshold level. When the RF tag 10 is re-powered, it is permitted to download and use the state information retained in the mirror latches
30 mechanism 2. So, when the RF tag 10 is re-powered, the state information maintained in the mirror latches mechanism 2 is read and used to reset the states of the RF tag 10. However before

the state information is used, the voltage across C_{Aux} must be checked to ascertain that it has not fallen to a threshold level where the information maintained in the mirror latches 2 is no longer trustworthy.

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Figure 4 shows a power-no-good signal 45 applied as an input to a flip flop circuit 41, another input to that flip flop circuit 41 being the output of a check circuit 42. When the power-no-good signal 45 falls while the V_{DD} on line 6 is
10 sufficient to power the RF tag 40, the check circuit 42 determines if the voltage V_{Aux} across the capacitor C_{Aux} 5 is high enough with respect to the value of the voltage V_{DD} . Thereby if the determined voltage is high enough, a signal 43 is outputted to permit the use of the information stored in the mirror
15 latches 2. If on the other hand, the voltage level of the capacitor C_{Aux} is determined to be less than the threshold, the integrity of the information contained in the mirror latches mechanism 2 is considered suspect and is not used. An example of a check circuit 42 for checking the voltage V_{Aux} across the
20 capacitor C_{Aux} is shown in Figure 5.

Figure 6a shows the voltage V_{DD} as a function of time during the energizing of the RF tag by a single burst of RF energy. When the RF burst is broadcast to the RF tag 10 (Figure 4), the
25 power supply V_{DD} (Figure 4) starts to charge the capacitor C_{Aux} (Figure 4). At time T_1 the voltage may charge the capacitor C_{power} (Figure 2) to a sufficiently high voltage to render the RF tag 10 operative, and the power-no-good signal POK_{-} will be removed. This signal POK_{-} is issued in the region 64 shown in
30 Figure 6b. to tell the electronic components of the RF tag 40 (Figure 4) that there is insufficient power for reliable operation. When V_{DD} reaches the threshold level for stable

operation at T_1 , the power-no-good signal POK_{-} falls and a power-good signal POK comes on as shown in Figure 6c.

Returning now to Figure 4, the power-no-good POK_{-} signal 45
5 is used to prevent C_{Aux} from charging when the voltage V_{DD} on line
6 is falling after the power burst has been applied and when the
voltage V_{DD} on line 6 is increasing as represented by region 64
(Figure 6b). When the power-no-good signal POK_{-} 45 falls at T_1
(Figure 6a), the transistor 1 is rendered conductive to apply
10 current to recharge C_{Aux} . Furthermore, to assure that the
voltage V_{Aux} 46 across the capacitor C_{Aux} is not changing while
the decision is being made as to whether to use the information
in the mirror latches mechanism 2 powered by the capacitor C_{Aux} ,
an optional delay circuit 44 may be used to assure that the
15 period allocated to decision making is long enough.

While the invention has been particularly shown and
described with respect to illustrative and preferred embodiments
thereof, it will be understood by those skilled in the art that
20 the foregoing and other changes in form and details may be made
therein without departing from the spirit and scope of the
invention that should be limited only by the scope of the
appended claims.

The following Appendix A is incorporated herein by reference in its entirety.

APPENDIX A

This invention is a methodology for enhancing RFID performance when identifying or writing to two or more tags. Both methodologies become crucial to performance when a substantial number of tags, for example ten or more, are being identified or written. The methodology is embodied by two commands that will specifically select RFID tags based on certain selection criteria. The criteria for selection can be set based on user requirements and the user can do the following operations

- 1)selection of any combination of a subset of available flags
- 2)selection based on matching flag condition
- 3)selection based on non-matching flag condition

The flags that are currently available are state_storage flag and write_ok flag. The state storage flag indicates whether or not the tag was in a specific state(DATA_EXCHANGE_STATE) prior to losing power and the write_ok flag indicates if the last write operation on the EEPROM was done with adequate power supply(i.e. a good write was done into the EEPROM memory matrix).

The two commands that perform the selection of tags are

- 1)Group select flags- this will move tags from the READY state to the ID state
- 2)Group unselect flags- this will move tags from the ID to the READY state.

Both command will do their respective operations only if the flags on a tag match the selection criteria.

Detailed description of the group select flags commands is as follows-

The various fields for group_select_flags for selecting on the write_ok flag and the state_storage flag are as follows:-

<preamble> <command> <bit_mask> <data> <crc>

Both the bit_mask and the data fields are one byte fields. The

bit_mask will enable selection on flags and once a bit flag is enabled, the value of the data field will enable selection on flag high or low. Eg if the last two bits of the bit_mask and the data field are used for state_storage and write_ok(LSB) in that order then a few scenarios:- (only last two bits for each field are shown are shown)

BM Data

- 11 11 - will select all tags with state_storage set and write_ok set
- 11 01 - will select all tags with state_storage not set and write_ok set
- 01 11 - will select all tags with state_storage set

The original description of the invention follows:

REVIEW OF CHIP STATE STORAGE CAPABILITY

OBJECTIVE

Tags losing power while in the middle of the Multi-Item protocol add enormous latency to the protocol efficiency. Tags can lose power while in the ID state or the DATA_EXCHANGE state. Intuitively tags losing power in the DATA_EXCHANGE add longer times to the protocol because they have to go through the ID state (without losing power) and finally end in the DATA_EXCHANGE state; whereas tags losing power in the ID state add lesser time overhead relatively. Thus if a technique that could prevent tags that were in the DATA_EXCHANGE state (and lost power) from coming back into the protocol to be identified, this would save considerable time. It must be noted that it is difficult to delineate the exact amount of overhead that the two situations (tags losing power in the ID state, tags losing power in the DATA_EXCHANGE state) contribute by themselves.

REQUIREMENTS FROM A SYSTEM STANDPOINT

- 1) To identify all the tags within the range of a reader (regardless of whether they were identified before or not)
- 2) To identify only tags that were identified (brought to DATA_EXCHANGE) but subsequently lost power
- 3) To avoid inclusion of tags that were identified once back into the protocol loop once again

SOLUTION

The above three requirements can be met with the following solution

The tag has the capability of storing a voltage (V_{STORAGE}) on a high impedance node that is charged high when the tag goes to DATA_EXCHANGE state- the voltage would also be discharged when an INITIALISE command or an appropriate GROUP_SELECT command is issued from the reader.

REVIEW OF CHIP STATE MACHINE ARCHITECTURE WITH THE ABOVE MODIFICATION

The Gamma ASIC has three major states- READY, ID and DATA_EXCHANGE. With the above modification, the following table indicates the storage value vs. tag state

TAG STATE	V _{STORAGE}
READY	Can be high or low
ID	Low
DATA_EXCHANGE	High

V_{STORAGE} is high in the READY state if the tag was previously identified and lost power and went back into the ready state.

ADDITIONAL COMMANDS REQUIRED

Additional commands have to be added to the capability of the reader to enable selection/non-selection of tags with V_{STORAGE} high/low

GROUP_SELECT_EQ_SS- This command will select only tags that have V_{STORAGE} high.

GROUP_SELECT_EQ_NSS-This command will select only tags that do not have V_{STORAGE} high(tags that were not identified, or tags which had V_{STORAGE} high but the voltage discharged off, or tags which had the high V_{STORAGE} reset to low with an INITIALISE command)

Note that a GROUP_SELECT_EQ command will select all the tags; and all other commands will not differentiate between a tag that has V_{STORAGE} high vs. V_{STORAGE} low.

Incorporation By Reference

U.S. Patents 5,550,547, 5,850,181 and 5,673,037 are hereby incorporated by reference as providing background information to assist in understanding the foregoing disclosure.

U.S. patent applications 10,373,628 filed 02/24/2003, 60/493,248 filed 08/07/2003, and 60/493,688 filed 08/07/2003, (Attorney Docket 203117PI), and an Application filed via Express Mail Label EV 331 318 018 on 08/18/2003 in the names of Martinez, Heinrich, Pillai and Ramamurthy and entitled "Radio Frequency Identification System and Method for Increasing Identification Throughput", Attorney Docket 203117PA are each hereby incorporated herein by reference in their entireties, including appendices, drawings and incorporated material. Also incorporated herein by reference in its entirety is each of ISO/IEC 18000 Part 6 – RFID Air Interface standard for item management at UHF, as available currently, and ISO/IEC JTC 1/SC 31/WG 4/SG 3 N311as dated 2002-05-04, ISO/IEC CD 18000-6, entitled "Information Technology – Radio Frequency Identification (RFID) for Item Management – Part 6: Parameters for Air Interface Communications at 860-930 MHz".